BERYLLIUM

By Larry D. Cunningham

Domestic survey data and tables were prepared by Jesse J. Inestroza, statistical assistant, and the world production table was prepared by Linder Roberts, international data coordinator.

Beryllium (Be), silver in color and one of the lightest of all metals, has one of the highest melting points (about 1,280° C) of all light metals. It has physical and chemical properties, such as its stiffness, resistance to corrosion from acids, and electrical and thermal conductivity, that make it useful for various applications in its alloyed, oxide, and metallic forms. Only two beryllium minerals, beryl and bertrandite, are of commercial importance; beryl contains about 4% beryllium, and bertrandite contains less than 1% beryllium. Bertrandite is the principal beryllium mineral mined in the United States, and beryl is the principal mineral produced in the rest of the world.

In 2002, U.S. production of beryllium ore and total ore consumption for the production of beryllium alloys, beryllium metal, and beryllium oxide decreased from those of 2001 (table 1). The telecommunications and computer sector was the major market for beryllium.

The Defense National Stockpile Center (DNSC), U.S. Department of Defense, offered and sold selected beryllium materials from the National Defense Stockpile (NDS). Yearend published price quotations for selected beryllium products remained unchanged from those of 2001; however, price quotations for some selected beryllium products were discontinued in early 2002 and early 2003. Overall U.S. exports of beryllium were up substantially, and overall imports of beryllium were down significantly in 2002 compared with those in 2001.

Legislation and Government Programs

To ensure a supply of beryllium during an emergency, various materials have been purchased for the NDS. The stockpile goal for beryllium metal, effective as of December 28, 2001, was about 45 metric tons (t) (table 2). However, a total of 155 t of hot pressed beryllium metal is proposed as a requirement in the 2003 requirement report to the Congress. For fiscal year (FY) 2002 (October 1, 2001, through September 30, 2002), the DNSC sold about 18 t of beryllium metal valued at about $2.84 million from the NDS. There were no sales of beryl ore and beryllium copper master alloy (BCMA) from the NDS. As of September 30, 2002, beryllium inventory sold but not shipped from the NDS included about 840 t of beryl ore (about 34 t of beryllium content); about 250 t of BCMA (about 10 t of beryllium content); and about 248 t of beryllium metal (U.S. Department of Defense, 2003, p. 12, 48, 53-54).

In its Annual Materials Plan for FY 2003 (October 1, 2002, through September 30, 2003), the DNSC had authority to sell about 3,630 t of beryl ore (about 145 t of beryllium content) (actual quantity limited to remaining sales authority or inventory), about 907 t of BCMA (about 36 t of beryllium content) (actual quantity limited to remaining sales authority or inventory), and about 36 t of beryllium metal (U.S. Department of Defense, 2003, p. 8, 10). For FY 2003, through May 31, 2003, the DNSC sold about 32 t of beryllium metal valued at about $4.93 million from the NDS. There were no sales of beryl ore and BCMA from the NDS. The DNSC also proposed maximum disposal limits in FY 2004 of about 3,630 t of beryl ore (actual quantity limited to the remaining sales authority or inventory), about 1,090 t of BCMA (about 44 t of beryllium content) (actual quantity limited to the remaining sales authority or inventory), and about 36 t of beryllium metal (Bureau of Industry and Security, 2002).

Production

The U.S. Geological Survey collects beryllium data from two voluntary surveys of U.S. operations. In 2002, respondents to the "Beryllium" and the "Mineral Concentrate and Beryllium Ore" surveys produced 100% of total domestic mine shipments presented in tables 1 and 7. A small number of unidentified producers may have shipped negligible quantities of byproduct beryl, which have not been included. In 2002, domestic mine shipments were down compared with those of 2001; continued slowdown in overall beryllium demand contributed to the decline.

The United States, one of only three countries that process beryllium ores and concentrates into beryllium products, supplies most of the rest of the world with these products. Brush Wellman Inc., Cleveland, OH, mined bertrandite and converted ore of this mineral, along with imported beryl, into beryllium hydroxide at its operations near Delta, UT. Beryllium hydroxide was shipped to the company's plant in Elmore, OH, where it was converted into beryllium alloys, metal, and oxide.

NGK Metals Corp. (a subsidiary of NGK Insulators, Ltd. of Japan) headquartered in Reading, PA produced beryllium alloy products at a plant in Sweetwater, TN. Because NGK Metals does not have facilities to process beryllium ores and concentrates, the company purchases beryllium hydroxide from Brush Wellman.

Environment

Because of the toxic nature of beryllium, the industry must maintain careful control over the quantity of beryllium dust and fumes in

the workplace. The U.S. Environmental Protection Agency issues standards for certain hazardous air pollutants, including beryllium, under the Clean Air Act, and the Occupational Safety and Health Administration (OSHA) issues standards for airborne beryllium particles. To comply with these standards, plants are required to install and maintain pollution-control equipment. In beryllium-processing plants, harmful effects are prevented by maintaining clean workplaces; requiring the use of safety equipment, such as personal respirators; collecting dust, fumes, and mists at the source of deposition; establishing medical programs; and implementing other procedures to provide safe working conditions. Standards for exposure to beryllium were under review by OSHA and private standard-setting organizations (Petkof, 1985, p. 80; Rossman, Preuss, and Powers, 1991, p. 278-280; Kramer, 1998, p. 107-108; Brush Engineered Materials Inc., 2003, p. 18). Control of potential health hazards adds to the final cost of beryllium products.

Consumption

In 2002, domestic beryllium-containing ore consumption continued to trend downward. According to its annual report, Brush Engineered Materials Inc.'s (BEM) worldwide sales were about $373 million in 2002 compared with about $473 million in 2001 and about $564 million in 2000 (company record sales). The decline in sales was due in large part to soft demand from the telecommunications and computer market. The domestic market accounted for 72% of the company's revenue, with telecommunications and computer (30%), automotive electronics (17%), industrial components (15%), and optical media (14%) the leading revenue markets. Metal Systems Group, which included Brush Wellman Inc.'s Alloy Products and Beryllium Products business units, had sales of about $228 million compared with about $296 million in 2001 and accounted for more than 60% of total company sales and assets. Alloy Products, the company's largest business unit, accounted for more than 40% of company revenue, supplying strip and bulk products. Alloy strip products (primarily copper beryllium and nickel beryllium alloys) were manufactured at company facilities in Elmore, OH, and Reading, PA. Strip product sales and the quantity of material sold were down by 27% and 17%, respectively, compared with those of 2001. Alloy bulk products containing beryllium were manufactured at the Elmore facility. Bulk product sales and quantity of material sold were down by 37% and 33%, respectively. Beryllium Products (consisting of pure beryllium metal and beryllium aluminum alloys) were manufactured at the Elmore facility and in Fremont, CA. Sales were up by 14% compared with sales in 2001 mostly owing to improved defense-related demand. Company international sales totaled about $104 million ($71.8 million from international operations, with facilities in Germany, Japan, Singapore, and the United Kingdom, and $32.5 million from the exports of U.S. operations) compared with about $134 million in 2001. Company international sales were mostly to Canada, the Pacific rim, and Western Europe. Telecommunications and computers as well as automotive electronics were the major markets served by the international operations (Brush Engineered Materials Inc., 2003, p. 1-2, 9, 12, 14-15, 17).

BEM has agreements with the U.S. Defense Logistics Agency to purchase beryl ore, BCMA, and beryllium metal from the NDS. Purchases totaled approximately $13.7 million in 2000, $6.4 million in 2001, and $3.9 million in 2002. Annual purchase commitments totaled $3.7 million in 2003, $5.1 million in 2004, $5.8 million in 2005, $6.2 million in 2006, and $6.8 million in 2007. The purchased material serves as raw material input for operations within the company's Brush Wellman and Brush Resources Inc. subsidiaries (Brush Engineered Materials Inc., 2003, p. 43).

BEM also has a long-term arrangement, signed in 2000 and amended in 2001, with Ulba/Kazatomprom in Kazakhstan and their marketing representative Nukem Inc. in New York, NY, to purchase BCMA from 2002 through 2010. BEM will purchase a stated quantity of BCMA from Nukem that is sourced from Ulba/Kazatomprom. Purchases of beryllium-containing material from Nukem totaled $3.3 million in 2001 and $0.2 million in 2002. Annual base purchase commitments through 2010 totaled $6.9 million in 2003, $8.6 million in 2004, $10.3 million in 2005, $12 million in 2006, and $13.7 million per year thereafter. Nukem will maintain minimum quantities of BCMA at BEM's Elmore facility in excess of annual base purchase commitments. The agreement could be terminated by both parties at any time with written notice for various causes of action (Brush Engineered Materials Inc., 2003, p. 43).

U.S. apparent consumption of all beryllium materials was estimated to be about 180 t of contained beryllium in 2002 compared with about 230 t in 2001.

Beryllium-Copper Alloys.—Beryllium-copper alloys, most of which contain approximately 2% beryllium, are used in a wide variety of applications. These alloys are used because of their electrical and thermal conductivity, good corrosion and fatigue resistance, high strength and hardness, and nonmagnetic properties. Beryllium-copper strip is manufactured into connectors, springs, and switches for use in applications in aerospace, automobiles, computers, factory automation, home appliances, instrumentation and control systems, and radar and telecommunications. The principal use of large-diameter beryllium-copper tubing is in oil- and gas-drilling equipment and in bushings and bearings in aircraft landing gear and heavy machinery. Connectors in fiber-optic telecommunications systems are the main application for beryllium-copper rod. Small pluggable sockets for joining integrated circuits to printed circuit boards are the main application for beryllium-copper wire. Beryllium-copper bar and plate are used in resistance-welding parts components for machinery and materials-handling systems and for molds to make glass, metal, and plastic components.

Beryllium also is used in small quantities in aluminum- and nickel-base alloys. Miniature electronic connector components that operate at high temperatures are the main use for beryllium-nickel alloys. These alloys also are used in automotive passive restraint systems (airbags). Beryllium-aluminum alloys are used as castings by the aerospace industry. The addition of small quantities of beryllium to magnesium alloys inhibits oxidation.

Beryllium Metal.—Beryllium metal is used principally in aerospace and defense applications. Its dimensional stability within a wide temperature range, high level of stiffness, and light weight make it useful in inertial guidance systems, military aircraft brakes, satellite and space vehicle structures, and space optical system components. Because beryllium is transparent to most x rays, it is used for x-ray windows. In nuclear reactors, beryllium also serves as a canning material and a neutron moderator and in control rods. In

the past, the metal was used as a triggering device in nuclear warheads. Other applications for metallic beryllium include audio components, high-speed computer components, and mirrors. In the National Aeronautics and Space Administration's space shuttles, beryllium is used for some brake components and structural parts.

Beryllium Oxide.—Beryllium oxide (BeO, beryllia), which has a high level of hardness and strength, is an excellent heat conductor. This material also acts as an electrical insulator in some applications. BeO serves mainly as a substrate for high-density electronic circuits for automotive ignition systems, high-speed computers, lasers, and radar electronic countermeasure systems. Because it is transparent to microwaves, microwave communications systems and microwave ovens may use BeO.

Because the cost of beryllium is high compared with that of other materials, it is used in applications in which its properties are crucial. Graphite, steel, and titanium may be substituted for beryllium metal in some applications, and phosphor bronze may be substituted for beryllium-copper alloys, but these substitutions can result in substantial loss in performance. In some applications, aluminum nitride may be substituted for BeO.

Prices

Yearend price quotes for beryllium materials and products are shown in table 3. The American Metal Market (AMM) published prices for selected beryllium products (discontinued in February 2002) were as follows: beryllium vacuum-cast ingot, a range of $325 per pound to $350 per pound; beryllium-aluminum alloy, $260 per pound, unchanged since January 1995; BeO powder, $100 per pound, unchanged since June 2000; and beryllium-copper strip, $8.90 per pound, unchanged since January 1993. The AMM published price for 99% beryllium metal powder was discontinued in February 2003 at a range of $350 per pound to $400 per pound. The Platts Metals Week published prices for selected beryllium products were as follows: BCMA, $160 per pound of contained beryllium; beryllium copper alloy strip, $9.95 per pound; and beryllium copper casting ingot $6.40 per pound. The Metal Bulletin published price for beryl ore was discontinued in October 2001 at a range of $75 per short ton unit to $80 per short ton unit of contained BeO.

Significant events affecting beryllium prices since 1958 include the following: 1969, bertrandite mine established in the United States, providing a significant raw materials source; 1977, effects of inflation, increased energy costs, and additional costs associated with complying with air emission standards resulted in increased prices; 1979, beryllium metal price set by one producer; 1988, purchase of beryllium metal for the NDS; 1990, conversion of NDS beryl ore to beryllium metal for the NDS; and 1991, recession and dissolution of the Union of Soviet Socialist Republics (Cunningham, 1999).

Foreign Trade

Data for U.S. exports and imports are summarized in tables 4 and 5, respectively. Overall beryllium exports were up substantially compared with those of 2001. In descending order, Japan, Germany, Canada, the Netherlands, Korea, and France were the major recipients of the materials, with about 90% of the total. Overall beryllium imports were down by more than 40% owing to significant decreases in beryl ore imports from Brazil and BCMA imports from Russia. The schedule of tariffs applied during 2002 to U.S. imports of selected beryllium materials is found in the U.S. International Trade Commission's Publication 3477, 2002 Harmonized Tariff Schedule of the United States (U.S. International Trade Commission, 2001).

Net import reliance as a percentage of apparent consumption is used to measure the adequacy of current domestic beryllium production to meet U.S. demand. For 2002, net import reliance as a percentage of apparent consumption was estimated to be about 50% compared with about 57% in 2001. In descending order based on contained beryllium, Japan, Australia, Germany, and Brazil were the major sources for U.S. beryllium imports, accounting for about 85% of the total. Other sources of imports included France, Kazakhstan, Nigeria, and the United Kingdom.

The U.S. Census Bureau does not separately identify all imports and exports of beryllium products. The Journal of Commerce Port Import/Export Reporting Service (PIERS) provides some data on materials that are transported by ship. According to PIERS, about 730 t (gross weight) of beryllium products (mostly beryllium ore from Brazil, Belgium, and the United Kingdom and beryllium-copper from Japan) was imported in 2002. Exports of beryllium products (mostly beryllium compounds and beryllium-copper) totaled about 900 t, gross weight; Japan, Hong Kong, and Italy received most of this material.

World Review

Annual world beryl production capacity (metric tons of contained beryllium) is listed in table 6. Estimated world beryl production (metric tons of gross weight) is listed in table 7. In 2002, estimated world beryl production (including bertrandite ore) decreased by about 14% compared with that of 2001 because of continued decline in production in the United States. The two major producers, Russia and the United States, accounted for more than 95% of total production.

Kazatomprom, Kazakhstan's national nuclear concern, planned to invest more than $20 million to expand its production capability. Investment at the Ulba Metallurgical Plant included plans for a new carbothermy unit to produce beryllium alloying additives and an additional hydrometallurgical facility for the production of beryllium hydroxide. The new facilities will support Ulba's long-term beryllium supply arrangement with Brush Wellman. Kazatomprom owns 90% of Ulba shares. Kazakhstan reportedly produced 737 t of unprocessed beryllium (exclusive of mine production) in 2001, an increase of more than 70% compared with that of 2000. In 2002, Kazakhstan was expected to account for more than 20% of total world beryllium production (exclusive of mine production) (Interfax

International, Ltd., 2002d-f).

In September, Ulba and Russia's Moscow Nonferrous Metals Processing Plant formed a 50-50 joint venture to produce beryllium bronze products. The joint venture was formed to increase the sale of beryllium bronze in the Russian market. Kazakhstan, a beryllium producer, has no domestic beryllium market, whereas Russia, a nonberyllium producer, has an increasing beryllium market. Ulba will produce beryllium bronze ingots, and the Moscow plant will roll/work the ingots into products for use in electrical and electronic applications (Interfax International, Ltd., 2002a-c).

Outlook

The United States is expected to remain self-sufficient with respect to most of its beryllium requirements. In 2002, the United States consumed about 120 t of beryllium in beryllium-bearing ores compared with about 170 t in 2001. At yearend 2002, Brush Engineered Materials reported proven bertrandite reserves in Juab County, UT, of about 6.1 million metric tons with an average grade of 0.267% beryllium. This represents about 16,300 t of contained beryllium compared with about 17,700 t in 2001. Proven reserves were reported to be sufficient for another 75 years of operation based on average production levels in recent years. About 87% of the beryllium is recovered from the ore during the extraction process. As of 2001, in lieu of leasing, the company owned approximately 95% of its proven mineral reserves (Brush Engineered Materials Inc., 2003, p. 20-21).

Beryllium alloys, primarily beryllium-copper, are expected to remain the dominant form of consumption for beryllium. Beryllium demand from the telecommunications sector, which is the largest market, was declining. For the medium term, the decline in demand from the telecommunications sector was expected to be offset by increased demand for beryllium-copper in automotive electronics and computers. Demand for beryllium-copper products for undersea communications equipment and pipe products for the oil and gas industry was also expected to increase. Beryllium-aluminum alloys containing up to about 65% beryllium, compared with beryllium-copper alloys containing about 2% beryllium, may stimulate demand in such applications as aerospace and computers. Beginning in 2003, annual world beryllium consumption was forecast to increase by about 2% per year (Roskill Information Services Ltd., 2001, p. 1-5, 120-123).

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TABLE 1
SALIENT BERYLLIUM MINERAL STATISTICS

(Metric tons of beryllium metal equivalent)

	1998	1999	2000	2001	2002
United States, beryllium-containing ores:					
Mine shipments	243	200	180	100	80
Imports for consumption, beryl[1]	13	1	--	19	10
Consumption, reported	270	260	240	170	120
Yearend stocks	80	20	115	100	90
World, production[1]	289	248	226	145	124

-- Zero.

[1]Based on a beryllium metal equivalent of 4% in beryl.

TABLE 2
BERYLLIUM IN GOVERNMENT INVENTORIES AS OF DECEMBER 31, 2002

(Metric tons of beryllium content)

Material	Stockpile goal[1]	Disposal authority	National Defense Stockpile inventory	
			Uncommitted	Committed
Beryllium ore	--	227	227	34
Beryllium-copper master alloy	--	41	41	10
Beryllium metal	45	245	290	9

-- Zero.

[1]Goal effective as of December 28, 2001.

Source: Defense National Stockpile Center.

TABLE 3
BERYLLIUM PRICES AT YEAREND 2002

(Dollars per pound unless otherwise specified)

Material		Price
Beryl ore		(1)
Beryllium vacuum-cast ingot, 98.5% pure, in lots up to 1,000 pounds		$325-350 [2]
Beryllium metal powder, in 1,000- to 4,999-pound lots and 99% pure		350-400 [3]
Beryllium-copper master alloy	per pound of contained Be	160
Beryllium-copper casting alloy		5.52-6.30 [2]
Beryllium-copper in rod, bar, wire		9.85 [2]
Beryllium-copper in strip		8.90 [2]
Beryllium-aluminum alloy, in lots up to 100 pounds; 62% Be, 38% Al		260 [2]
Beryllium oxide powder, in 10,000-pound lots		100 [2]

[1]The published price for beryl ore was discontinued in October 2001 at a range of $75 per short ton unit to $80 per short ton unit of contained beryllium oxide.
[2]The price was discontinued in February 2002.
[3]The price was discontinued in February 2003.

Sources: American Metal Market, Brush Wellman, Inc., Metal Bulletin, and Platts Metals Week.

TABLE 4
U.S. EXPORTS OF BERYLLIUM ALLOYS, WROUGHT OR UNWROUGHT, AND WASTE AND SCRAP, BY COUNTRY[1, 2]

(Gross weight)

	2001		2002	
Country	Quantity (kilograms)	Value (thousands)	Quantity (kilograms)	Value (thousands)
Canada	11,800	$319	17,400	$497
France	3,180	609	3,540	853
Germany	2,060	641	21,700	1,230
Hong Kong	--	--	2,200	35
Japan	13,600	2,880	92,900	1,950
Korea, Republic of	32	29	4,570	150
Netherlands	6,000	311	8,510	357
United Kingdom	1,500	776	2,350	1,410
Other	22,400 r	1,620 r	11,400	2,730
Total	60,600	7,190	165,000	9,210

rRevised. -- Zero.
[1]Consisting of beryllium lumps, single crystals, powder; and beryllium rods, sheets, and wire.
[2]Data are rounded to no more than three significant digits; may not add to totals shown.

Sources: U.S. Census Bureau and U.S. Geological Survey.

TABLE 5

U.S. IMPORTS FOR CONSUMPTION OF BERYLLIUM ORE, METAL, AND COMPOUNDS[1]

(Gross weight)

	2001		2002	
Material	Quantity (kilograms)	Value (thousands)	Quantity (kilograms)	Value (thousands)
Beryl ore	482,000	$237	274,000	$182
Beryllium-copper master alloy	264,000	1,760	108,000	1,170
Beryllium oxide and hydroxide	5,400	197	20	5
Beryllium, unwrought and waste and scrap	86,800	3,430	125,000	2,060

[1]Data are rounded to no more than three significant digits.

Sources: U.S. Census Bureau and U.S. Geological Survey.

TABLE 6
WORLD ANNUAL BERYL PRODUCTION CAPACITY, DECEMBER 31, 2002[1]

(Metric tons of beryllium content)

Continent and country	Capacity
North America, United States[2]	360
Africa:	
Madagascar	5
Mozambique	3
Rwanda	3
South Africa	3
Total	14
Asia, China	75
Europe:	
Kazakhstan	7
Portugal	3
Russia	70
Total	80
South America, Brazil	5
Grand total	534

[1]Includes capacity at operating plants as well as at plants on standby basis.
[2]Includes bertrandite ore.

TABLE 7

BERYL: ESTIMATED WORLD PRODUCTION, BY COUNTRY [1, 2]

(Metric tons of gross weight)

Country[3]	1998	1999	2000	2001	2002
Brazil	5 [4]	11 [4]	13 [4]	12 [r]	12
Kazakhstan	100	100	100	100	100
Madagascar[5]	30 [4]	20	2 [r, 4]	1 [r, 4]	1
Mozambique	--	--	-- [4]	1 [4]	1
Portugal	5	4	4	5	5
Russia	1,000	1,000	1,000	1,000	1,000
United States, mine shipments[6]	6,080	5,070	4,510	2,480	1,970
Zambia	7 [r]	7 [r]	7 [r]	7 [r]	7
Total	7,230 [r]	6,210	5,640 [r]	3,610 [r]	3,100

[r]Revised. -- Zero.

[1]World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Table includes data available through June 11, 2003.

[3]In addition to the countries listed, China produced beryl, and Bolivia may also have produced beryl, but available information is inadequate to formulate reliable estimates of production.

[4]Reported figure.

[5]Includes ornamental and industrial products.

[6]Includes bertrandite ore, calculated as equivalent to beryl containing 11% beryllium oxide.